

HD 207331 a new δ Scuti star in the Cygnus field: discovery and follow-up observations –

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Preliminary results on the discovery and follow-up observations of a new δ Scuti pulsator in the Cygnus field are presented. The variability of the star HD 207331 was detected while testing a Strömgren spectrophotometer attached to the H. L. Johnson 1.5-m telescope at the San Pedro Mártir observatory, México. CCD photometric data acquired soon after confirmed its variability. A few hours of *uvby* differential photoelectric photometry during three nights revealed at least two beating periods. A two-site observational campaign carried out during one week in 2009 confirms the multi-periodic nature of this new δ Scuti pulsator.

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1 Introduction

The δ Scuti-type pulsators are stars with masses between 1.5 and 2.5 M_{\odot} located at the intersection of the classical Cepheid instability strip with the main sequence. They have spectral types A and F, a period range between 0.5 h to 6 h, and generally pulsate with a large number of radial and nonradial modes excited by the κ mechanism. This makes them interesting targets for seismic studies. Therefore, any new detection of a δ Scuti star can be a valuable contribution to asteroseismology.

Since most of the δ Scuti stars are short period variables with typical photometric amplitude of 20 mmag, their oscillations can be easily detected from the ground. In fact, several δ Scuti stars have been discovered accidentally when taken as reference stars of observations of well known δ Scuti stars (e.g. Fox Machado et al. 2002 and 2007; Li et al. 2002). Others have been catalogued either in surveys devoted to the characterization of new variables or, as in this case, when considered as constant stars while testing observatory equipment. In particular, this paper presents a summary of the observations which yielded the discovery and characterization of the new δ Scuti star, HD 207331.

2 Observations

2.1 Discovery

The star HD 207331 (= SAO 51294, BD+42 4207, HIP 107557) was observed in a sample of A-type stars during a

few hours on the night of September 27, 2007, in order to test the six-channel *uvby*– β spectrophotometer attached to the H. L. Johnson 1.5-m telescope of the San Pedro Mártir Observatory, Baja California, México. The variability of the star was clear, despite the fact that it had been classified in the SIMBAD database as a normal A0 star. CCD photometric observations of HD 207331, confirming its variability, were carried out on the night of September 30, 2007, with the 0.84-m telescope (Schuster et al. 2008; Fox Machado et al. 2008).

2.2 Follow-up observations

2.2.1 *uvby* differential photometry

uvby differential photometry of HD 207331 was also performed during three nights in November 2007 using the 1.5-m telescope and the six-channel Strömgren spectrophotometer. In particular, the star was monitored for about 3.5 h on November 11, for about 4 h on November 18, and 3.5 h on November 19. As a result of these observations, a multiperiodic characteristic of the star, with at least two beating periods, was found (for details see Fox Machado et al. 2008).

Encouraged by results obtained in that short run and in order to investigate its pulsation characteristics more accurately, we decided to perform a two-site observational campaign on HD 207331 during August/September 2009.

2.2.2 Two-site observations

The two observatories involved in the observational campaign are listed in Table 1 together with the telescopes and

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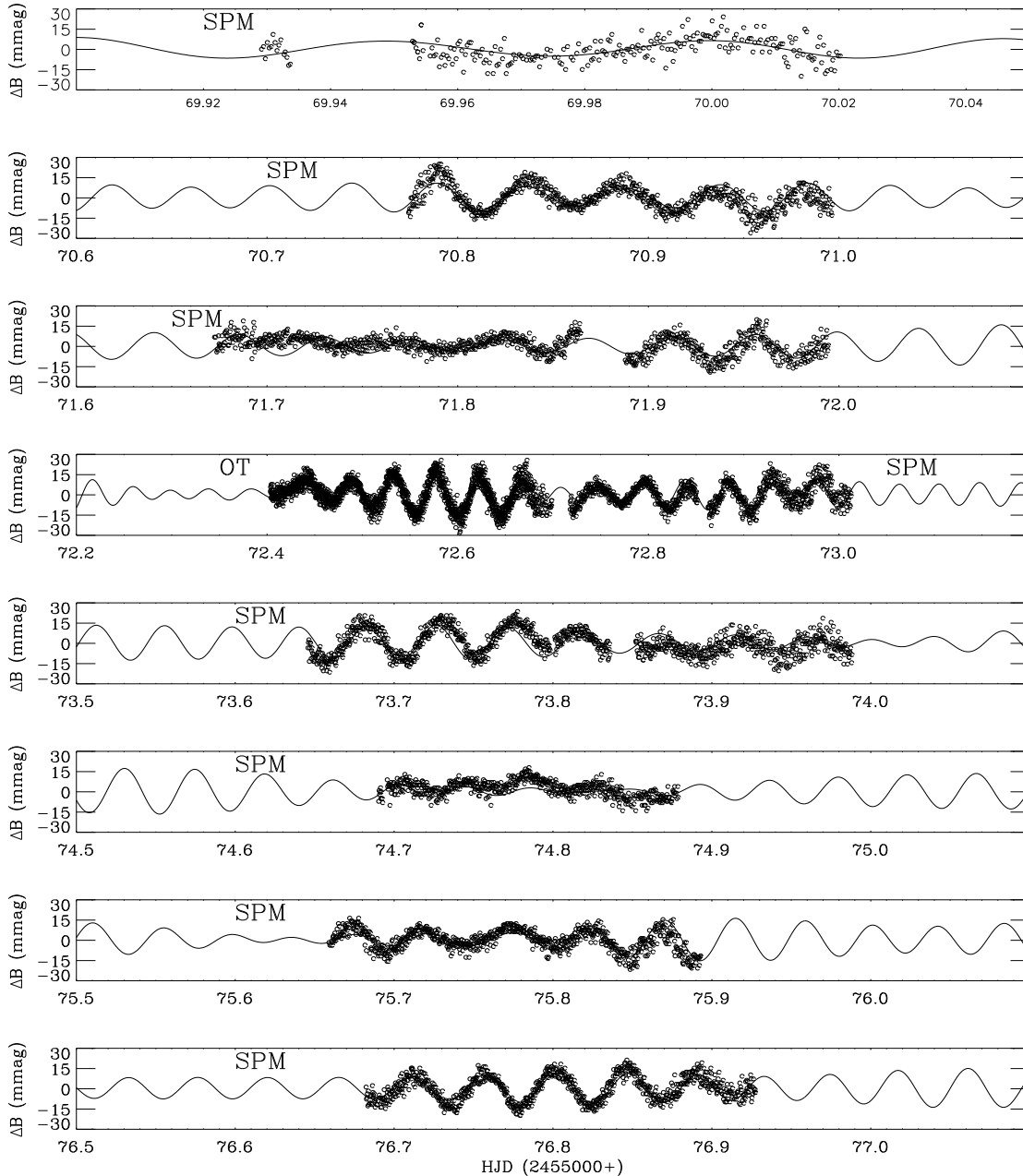


Fig. 1 CCD differential light curve: HD 207331 - Comparison. The fit of the four-frequency solution to the data is shown by solid line.

instruments used. Table 2 gives the log of observations. Bad weather conditions at the OT did not allow us to get more than one night of data. However, a total amount of 53.8 hours of useful data was obtained from the two sites.

The observations were obtained through a Johnson *B* filter. Figure 2 shows a section of a typical image of the CCD's field of view ($10' \times 10'$) at the IAC-80 telescope of the Teide observatory. The target star is labeled with number 2; comparison and check stars with 1 and 3, respectively. Table 3 shows the main observational parameters corresponding to the target and comparison stars as taken from the

SIMBAD database operated by the CDS (Centre de Données astronomiques de Strasbourg).

Sky flats, dark and bias exposures were taken every night at all sites. All data were calibrated and reduced using standard IRAF routines. Aperture photometry was implemented to extract the instrumental magnitudes of the stars. The differential magnitudes were normalized by subtracting the mean of differential magnitudes for each night. In Figure 1 the entire light curves, HD 207331 - Comparison, are presented. As can be seen from the fourth panel (from top to bottom) no overlapping of the observations was obtained for the one night of observing at OT, the 28th of August 2009.

Table 1 List of instruments and telescopes involved in the campaign. Observers' abbreviations correspond to the initials of the co-authors.

Observatory	Telescope	Instrument	Observers
Observatorio del Teide (OT, Spain)	0.80m	2048x2048 CCD	CZ
Observatorio San Pedro Mártir (SPM, México)	0.84m	1024x1024 CCD	WJS, JS, LFM

Table 2 Log of observations. Observing time is expressed in hours.

Day	UT Date 2009	Start Time (HJD 2455000+)	End Time (HJD 2455000+)	OT	SPM
1	Aug 26	69.93	70.02	-	2.185
2	Aug 27	70.77	71.00	-	5.335
2	Aug 28	71.67	72.70	7.086	7.731
4	Aug 29	72.72	73.01	-	7.076
5	Aug 30	73.65	73.99	-	8.218
6	Aug 31	74.69	74.88	-	4.536
7	Sep 01	75.66	75.89	-	4.592
8	Sep 02	76.68	76.93	-	7.085
	Begin	End	Total Time	OT	SPM
	Aug 26	Sep 02	53.844	7.086	46.758

Table 3 Position, magnitude, and spectral type of target, comparison, and check stars observed in the CCD frame.

Star	ID	RA (2000.0)	Dec (2000.0)	V (mag)	SpTyp
Target	HD 207331	21 47 02	+43 19 19	8.3	A0
Comparison	BD+42 4208	21 47 12	+43 19 51	9.4	A0
Check	TYC 3196-1243-1	21 47 06	+43 18 58	10.9	-

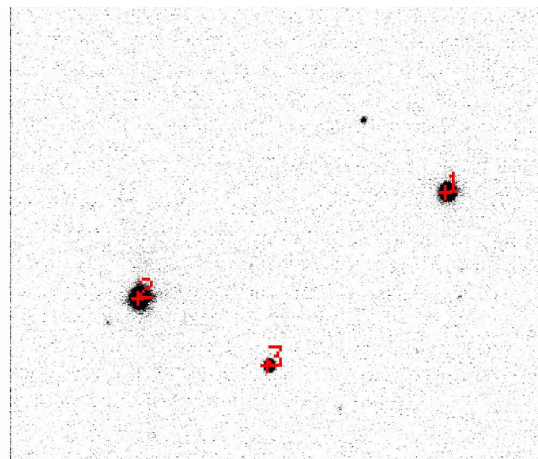
3 Period analysis

The period analysis has been performed by means of standard Fourier analysis and least-squares fitting. In particular, the amplitude spectra of the differential time series were obtained by means of Period04 package (Lenz & Breger 2005), which utilizes Fourier as well as multiple least-squares algorithms. This computer package allows us to fit all the frequencies simultaneously in the magnitude domain.

The amplitude spectrum of the differential light curve, HD 207331 - Comparison, is shown in the first plot of Fig. 3. As can be seen, HD 207331 shows high signal-to-noise peaks around 22 cycle day⁻¹. The subsequent plots in the figure, from left to right, illustrate the prewhitening process of the frequency peaks in each amplitude spectrum.

The frequencies have been extracted by means of a standard prewhitening method. In order to decide which of the detected peaks in the amplitude spectrum can be regarded as intrinsic to the star, Breger's criterion has been followed (Breger et al. 2003), where it was shown that the signal-to-noise ratio (in amplitude) should be at least 4 in order to ensure that the extracted frequency is significant.

The frequencies, amplitudes, and phases are listed in Table 4. Four significant frequencies have been detected in HD 207331. A comparison of this four-frequency solution to the data is displayed in Fig. 1 with the solid line.

**Fig. 2** The CCD FOV near HD 207331. 1 stands for the comparison star, 2 for HD 207331, and 3 for the check star. Some properties of the stars are listed in Table 1. North is up and East is right.

The main oscillations peaks have been found in the 20–25 cycle day⁻¹ range (i.e., ~ 231.4 – $289.25 \mu\text{Hz}$). In particular, the highest amplitude peak is located at 22.49 cd^{-1} ($260.21 \mu\text{Hz}$), and the next significant frequency is located at 20.09 cd^{-1} ($232.47 \mu\text{Hz}$). As was found in the discovery data, two beating pulsation modes are present in HD 207331, namely 24.54 cd^{-1} and 23.74 cd^{-1} . This is a common behavior in δ Scuti stars.

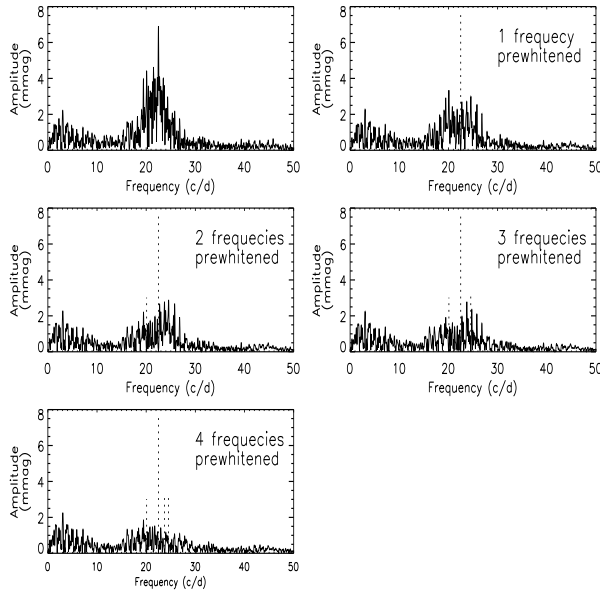


Fig. 3 Pre-whitening process in HD 207331. In each plot, from left to right, the highest amplitude peak is selected and removed from the time series, and a new spectrum is obtained.

Table 4 Frequency peaks detected in the light curve: HD 207331 - Comparison. S/N is the signal-to-noise ratio in amplitude after the prewhitening process.

Freq. (c/d)	A (mmag)	$\varphi/(2\pi)$	S/N
22.4880	7.76	0.18	13.7
20.0923	3.02	0.90	5.1
24.5384	3.22	0.32	6.3
23.7409	3.18	0.85	5.9

4 Discussion and conclusion

The determination of the evolutionary stage of a field star requires precise estimates of its global parameters. In the case of HD 207331, there is little information in the literature about its physical parameters. In particular, the Hipparcos catalogue (Perryman et al. 1997) provides a parallax of 3.31 ± 0.88 mas, from which a distance of 302 pc can be estimated. The large relative error of the measured distance ($\sigma(\pi)/\pi \sim 0.27$) implies $\sigma(M_V) \sim 0.6$ mag, making the Hipparcos absolute magnitude very imprecise for HD 207331.

Therefore, with the information available it is not possible to make a reliable seismic modeling for HD 207331. However, the complicated oscillation spectrum of HD 207331, with two beating modes, points to it being a fast rotating δ Scuti star. This would imply that the four frequencies listed in Table 4 are due to nonradial oscillations. In fact, as is well known, most of the δ Scuti stars are rapid rotators with low amplitudes of pulsations, and pulsating with nonradial modes (e.g. Fox Machado et al. 2006). Nonethe-

less, more precise information about its evolutionary stage is needed for a more conclusive study.

A summary of the observations which led to the discovery and characterization of the new δ Scuti star HD 207331 has been presented. The star shows complicated pulsations as do most of the δ Scuti stars. To date our observations represent the most extensive work on HD 207331.

4.1 Future Work

For the future, we will make spectroscopic observations of HD 207331 to obtain an accurate MKK spectral classification to fix more exactly the basic physical parameters of this star in order to be able to make a reliable seismic modeling. Also, spectroscopic observations will be carried out to test whether this δ Scuti star rotates as rapidly as we might expect. In addition, more differential photometric observations, better distributed in time, are needed to better understand this interesting object.

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